

Perception of Aircraft Deviation Cues

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To begin to address the need for new displays, required by a future airspace concept to support new roles that will be assigned to flight crews, a study of potentially informative display cues was undertaken. Two cues were tested on a simple plan display – aircraft trajectory and flight corridor. Of particular interest was the speed and accuracy with which participants could detect an aircraft deviating outside its flight corridor. Presence of the trajectory cue significantly reduced participant reaction time to a deviation while the flight corridor cue did not. Although non-significant, the flight corridor cue seemed to have a relationship with the accuracy of participants' judgments rather than their speed. As this is the second of a series of studies, these issues will be addressed further in future studies.

Outline of the concept

The Terminal Area Capacity Enhancing Concept (TACEC) is being developed as one participating concept in the NASA Virtual Airspace Modeling and Simulation (VAMS) Program. VAMS' aim is that revolutionary concepts that meet future air traffic demand, i.e., increase capacity, are developed through ideas shared by members of industry, government, and academia (Miller, Dougherty, Stella, & Reddy; 2005). TACEC focuses on the terminal domain and addresses the current (as of 2002) constraints within this airspace. TACEC's objective is that, in the future, multiple aircraft could land almost simultaneously on closely-spaced parallel runways. To do this will require a high level of flight automation in the terminal domain and much synchronization between aircraft and ground systems, with this centralized system generating optimized 4D flight profiles to land/depart these multiple aircraft. (More detail about the concept itself is provided in Miller, et al., 2005; and Miller & Dougherty, 2004.) In addition to the infrastructure improvements, such as high-speed data link, improved surveillance, and highly automated scheduling systems that will be required (Miller & Dougherty, 2004), new roles will emerge for air traffic controllers and flight crews. To support the flight crew in their new responsibilities, interfaces that display relevant and essential information are required.

TACEC envisages that one of the new roles required will be for the copilot of each aircraft to monitor other aircraft in the formation from the time aircraft form up, during initial approach, until landing on the parallel runways. The copilot will monitor the other aircraft, in particular the aircraft just in front of the ownship in the formation, for any signs that these aircraft are blundering¹ out of their assigned flight corridors. (At this point the flight crew would have to make an 'escape' go-around maneuver to pull out of the formation, and potentially harms way.) A display will be required to assist the copilot to monitor the formation aircraft. The display will need to have an appropriate visualization that makes blunders salient.

Issues for display development

Previous research (Houck & Powell; 2003) found that pilots responded most quickly to bank angle changes when the task was to follow a leading aircraft. They were least responsive to heading angle changes. How to best represent a deviation like this on a monitoring display is a key issue that the study reported in this paper set out to address. Houck & Powell found pilot performance improved markedly when they used a prototype tunnel-in-the-sky display for the ownship while tasked to follow a lead aircraft. It is possible a copilot would benefit from similar tunnel or corridor cues if they were monitoring a lead aircraft.

¹ Blunders are interpreted here as deviations of an aircraft from its flight path, and partially (or wholly) outside its flight corridor.

The reference bar was presented in two ways – as a flight corridor (Figure 1d.) or as two edge 'boundary' lines to the flight corridor (Figure 1c.). In the third condition, there were no reference bars (1a.). The center trajectory-line, when it was present, was displayed through the center of the aircraft (1b.). The three deviation conditions were a blunder of the aircraft from its flight path to the left, partially out of its flight corridor, a blunder to the right, and no blunder. If a blunder did occur, it was at a constant speed.

To prevent participants learning the three blunder patterns, noise was added to the aircraft's flight path. The 'noise' was a slight deviation of the aircraft around its actual trajectory. There were six noise effects, so when these were coupled with the blunder variable, this gave 18 flight paths comprised of a blunder plus a noise deviation component.

Scenario

As shown in Figure 1, in the display for the study, one aircraft was represented as a two dimensional plan view in a generic airspace with no terrain or geographical cues. The only reference tools were the cue conditions provided by the research team. Participants identified if the observed aircraft blundered from its assigned straight-ahead flight trajectory by pressing the ← or → keys, as appropriate.

Each trial lasted nine seconds. Participants were able to indicate whether they thought the aircraft was blundering (by pushing an arrow key) for the first eight seconds of each trial. During this time, participants could change their indicated perception as many times as they wished by pushing one of the arrow keys. On the ninth second, participants were given feedback about whether their most recent indicated perception (key press) was correct or incorrect.

Data collection

Each participant read a sheet that contained basic instructions for the study, completed 18 practice trials, and then continued to complete 108 trials (18 paths x 6 cue conditions). The practice trials were always presented in the same order but the 108 data collection trials were presented randomly. Participants started a trial by pressing the space bar, which allowed them to pause at any point during the study between trials.

Two dependent variables were collected: participant reaction time to their final judgment, and the correctness of that judgment, for which they were given feedback.

Results and discussion

From our hypotheses, there were two main lines of enquiry for this study. The first was, in general, how accurate participants were and the type of perceptual judgment errors they made. The second was which cues were of most assistance to participants in determining when the aircraft was deviating from its flight path.

Accuracy of perceptions

Across the 4968 trials completed by the 46 participants, 4617 were judged correctly (92.93%). Thus, on average, each participant made just under 8 incorrect judgments (out of 108). The percentage of correct judgments in each cue condition varied, as shown in Table 1. There were no significant differences when tested using a Chi Square.

	No corridor or flight path edge	Flight path edge	Flight path corridor
Trajectory line	88.52%	95.65%	96.01%
No trajectory line	84.78%	96.37%	96.25%

Table 1. Percentage of correct responses in each of the six (3 x 2) cue conditions

Of the 351 incorrect judgments made, 197 (56.1%) were where the participant had made a judgment but had selected the wrong direction – a false positive. In the remaining 154 (43.87%) cases, the participant did not make an explicit judgment, which indicated they thought the aircraft was not blundering but was maintaining its straight-ahead trajectory – a false negative.

presence of a cue showing the aircraft's flight corridor did seem to have an impact on whether participants correctly judged the aircraft's deviation. The average number of incorrect responses when no flight corridor cues were present was 110, versus an average of 32 when there was a flight corridor cue. Thus, it seems that the presence of flight corridor information assisted participants to correctly determine whether the aircraft was deviating but did not assist them to make this judgment more quickly.

Houck and Powell (2000) calculated that pilots needed to react to blunders by a leading aircraft in two to three seconds when on very closely-spaced parallel approaches. Participants in the study reported above did not achieve this speed of reaction using the cues presented to them. The most rapid reaction time was, on average, 3.861s in the condition where the trajectory of the leading (and blundering) aircraft was displayed on a plan view – nearly a second slower than the time Houck and Powell calculated was available, but within the one to five second range they found for pilot response to yaw cues. Three factors may have contributed to these findings, firstly, participants in the present study were not pilots, and while they had received training on the task, the task was not presented in a flying context (and they were not instructed to try to respond in two seconds). Trained pilots may recognize, and therefore, react more quickly to the onset of a blunder. Secondly, bank angle was not displayed as a cue, the aircraft drifted horizontally out of its flight corridor rather than rolling out of it. Displaying bank angle may assist copilot-monitors as well as pilots. Thirdly, Houck and Powell presented an aggressive blunder of 30°, whereas our participants were presented with a far gentler blunder of 7.5 lateral feet/second.

Conclusions

The two cues were chosen to display information about a lead aircraft holding its position – its trajectory and its assigned flight corridor. While these cues assisted non-pilot participants to make judgments about whether the aircraft was blundering, they did not assist participants to judge as quickly as had been hypothesized. The presence of a trajectory cue did assist participants to make slightly quicker judgments but, although significant, this difference was less than half a second on average. The presence of flight corridors only approached significance in increasing participant reaction times but seemed to be linked to more accurate identification of the presence of a blunder. In just under half the cases (43.87%), incorrect judgments were false negatives, which are more concerning than false positives because they indicate that the early signs of a blunder were missed. The next step of this research will be to investigate other cues (such as displaying lead aircraft bank angle) to try to increase participant speed and accuracy in blunder detection.

References

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Acknowledgements

This work was completed under a Space Act Agreement between NASA Ames Research Center and Raytheon. We thank Ken Arkind and Mary Ellen Miller of Raytheon Network-Centric Systems for their guidance and support. This work was partially funded by Raytheon Network-Centric Systems.